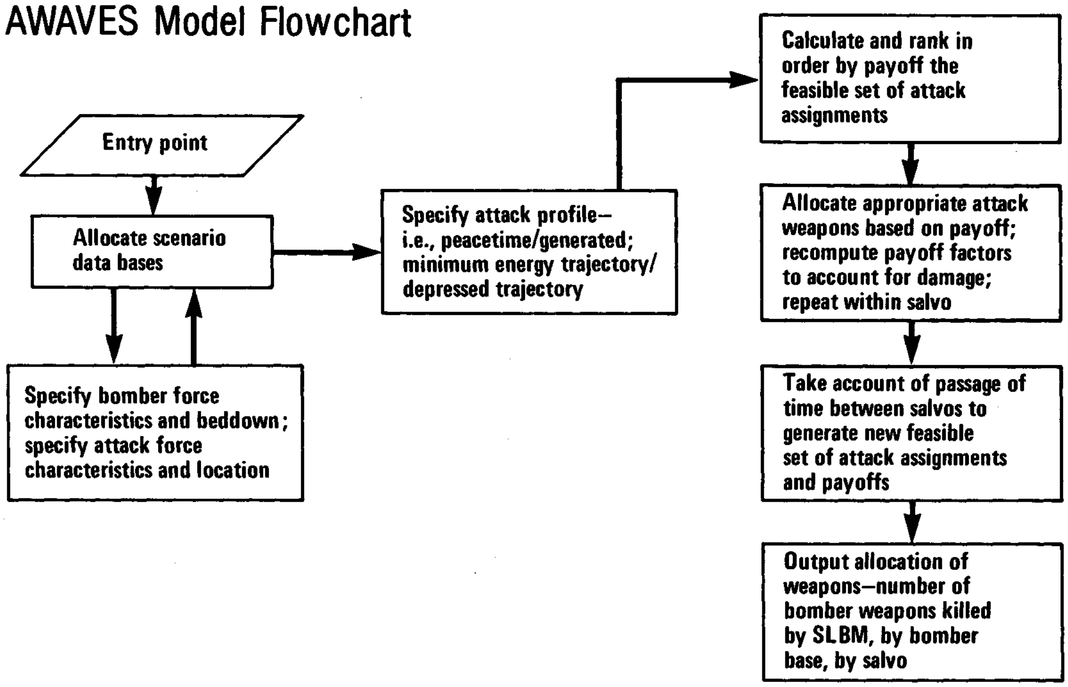
Figure E-1.
AWAVES Model Flowchart



FB-111 becomes the more valuable target. Thus, to the attacker, the time-relative value of the target is likely to be different from the absolute value of the target.

A flowchart of the AWAVES model is shown in Figure E-1. Accurate modeling of an attack on U.S. bomber bases requires taking account of as many factors as possible that contribute to and/or are affected by variability with time. In AWAVES, allocation of the attacker's weapons is done on a salvo-to-salvo basis, assigning weapons to the most advantageous targets for that salvo, noting the damage from previous salvos, and registering the changing profiles of the targets over time (see Figure E-1). The algorithm allocates the attacker's weapons to bomber bases according to the rank ordering of the expected "buy"--the number of bomber weapons expected to be destroyed per attacker's weapon expended--at any base. The damage algorithm, upon which the expected destruction is based, utilizes what is known as a "cookie-cutter," or ratio of areas, calculation. Such a calculation considers the relationship between the aircraft escape area--the area of uncertainty within which an attacker must allocate his weapons to destroy aircraft--and the lethal area that his attacking missiles can create. The distance from base of the first bomber to have flown out describes the radius of an ever-expanding circle within which all subsequent bombers might be found. This is the area of uncertainty. Likewise, each attacking weapon has an associated area within which its nuclear effects are assumed to be lethal to a particular target (see Figure E-2).

The variables affecting the bomber escape area or area of uncertainty are: the distance of the submarine from the bomber base, the missile time-of-flight, and the bomber flyout characteristics. These variables are, in turn, dependent upon a number of other variables as follows:

- o Distance of submarine from bomber base
  - location of base
  - distance of submarine from U.S. coast (and location)

- o Time of flight of SLBMs to their target
  - flight distance
  - type of missile--range
  - missile trajectory characteristics

- o Bomber take-off and flyout
  - attack detection and warning time
  - alert status/reaction time
  - flyout characteristics (speed, rate of climb, etc.)

The lethal area of the attacker's weapons is a function of the following variables:

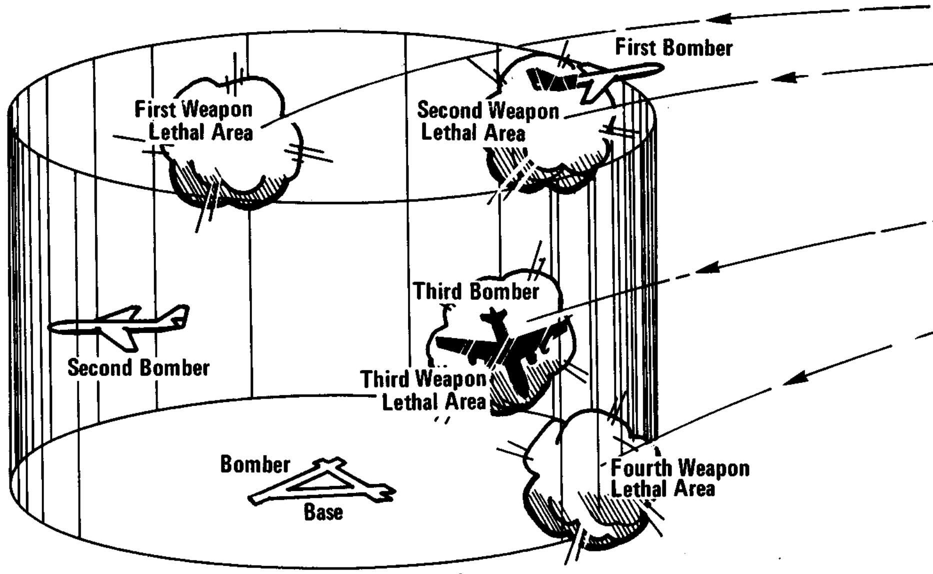
- o Yield of the warhead

- o Hardness (or resistance) of the aircraft to nuclear effects

- o Altitude of the aircraft (assuming a co-altitude burst)

Employing these variables (see Table E-1), AWAVES assigns the appropriate SLBM (if available) to the most lucrative target on the rank-ordered list of feasible assignments. If the SLBM is no longer available in that salvo, the next most advantageous target for which an SLBM is available is chosen. Damage must be taken account of on both an intra- and inter-salvo basis. This is accomplished by recomputing the payoff factors (for other SLBM types) at the base just attacked to take account of the damage, and then placing these new values in their proper places in the ordered list. After making the assignments of weapons to bases in a salvo, information on the

Figure E-2.
Illustration of "Cookie-Cutter" Damage Calculation



residual force at each base and the passage of time between salvos is used to generate a new set of feasible weapons assignments. 5/

The two scenarios described above were used in the effectiveness analysis portion of this study. These involve a surprise (peacetime alert posture), and an anticipated (generated alert posture) attack on U.S. bomber bases. In a generated case, more bombers are on alert, and their reaction time to an attack would be much shorter; conversely, the number of attacking SLBMs would likely be greater, and they might be launched from points closer to the coast. In the generated case, about 95 percent of

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5. It is important to note that although most parameters in quantitative models like this are treated as point estimates--for instance, bomber reaction time--there is, in fact, a great deal of uncertainty associated with them. Thus, while the results of force survivability are also presented as point estimates, the cumulative effect of these uncertainties renders them more useful for comparative assessments than for definitive statements.

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TABLE E-1. ASSUMED VALUES FOR SELECT VARIABLES

Peacetime Alert	Generated Alert
90-second attack detection and warning time	same
30% of B52s on alert; 40% of B-1s and ATBs on alert	95% of all aircraft (PAA) on alert
1.5 PSI hardness for B-52s; 3.0 PSI hardness for B-1/ATB	same
6.5-minute bomber reaction time from SLBM breakwater to first bomber takeoff	2.2-minute bomber reaction time
15 seconds between bomber takeoffs	same
15 seconds between SLBM launches	same
SLBM yields: 750 KT for SS-N-6/8; 500 KT, 3 RVs for SS-N-18; 100 KT, 9 RVs for SS-NX-20	same
Soviet SSBN patrol area: 700 miles of U.S. coast	Soviet SSBNs 300 miles off U.S.coast

the force is assumed to be on alert, the reaction time of the bombers is about 4 minutes faster, and the submarines are about 400 miles closer to the coast. Table E-1 shows the assumed values for some of the variables in AWAVES.

RESULTS

Table E-2 illustrates, by year, bomber pre-launch survivability expectations for the Administration force and for the alternative force without

TABLE E-2. BOMBER PRE-LAUNCH SURVIVABILITY (In percent)

	Peacetime Alert			Generated Alert		
	Non-Depressed Trajectory 6.5 Min. Reaction Time	Depressed Trajectory 6.5 Min. Reaction Time	Non-Depressed Trajectory 9.9 Min. Reaction Time	Non-Depressed Trajectory 2.2 Min. Reaction Time	Depressed Trajectory 2.2 Min. Reaction Time	Depressed Trajectory 6.5 Min. Reaction Time
Administration Force						
1983	94	65	74	85	73	16
1990	95	73	80	89	79	34
1996	92	71	78	85	76	23
Alternative Force						
1983	same	same	same	same	same	same
1990	92	62	74	88	77	21
1996	89	63	74	84	70	20

NOTE: These numbers represent the percentages of the alert bomber force expected to survive. All of the force not on alert--60 to 70 percent of the force in the day-to-day alert case and 5 percent of the force in the generated alert case--are presumed not to survive a Soviet attack. While the results of force survivability are treated here as point estimates, the cumulative uncertainties in the underlying parameters render them more useful for comparative assessments than for definitive statements.

the B-1B but with some improvements to the B-52s and with more ALCMs. Along with the assumed baseline peacetime and generated alert cases, two more stressful situations are displayed. The first of these cases assumes, for each of the alert postures, that the Soviets could fire their SLBMs on a so-called depressed-trajectory flight path. 6/ The Soviets have not, to date, demonstrated the capability to fly their ballistic missiles along this shallower, accelerated trajectory, but these results illustrate the implications for the survivability of the bomber force were such a threat to develop. The second of these cases assumes that the bomber response time to an attack is delayed beyond that assumed in the base case. Delayed bomber reaction time could occur as a result of warning system malfunction, human error, and the like. In the peacetime alert posture, the effect of delayed reaction time is illustrated under the current, non-depressed trajectory threat from Soviet SLBMs. In the generated alert case, the effect of delayed reaction time is illustrated under a depressed-trajectory SLBM threat. This represents the most stressful scenario for the bomber force.

Survivability Will Not Change Dramatically Over Time

One result suggested by the analysis is that the survivability of aircraft on alert will not change dramatically between 1983 and 1996. For example, the only case in which survivability changes by more than 10 percent is under the most stressful scenario--a depressed-trajectory, generated-alert threat with a delay in bomber reaction time. In this case, survivability more than doubles by 1990 with the introduction of the harder, faster B-1B bomber but declines again by 11 percentage points by 1996 as a result of the growth in the threat in the absence of arms-control limits. However, survivability remains quite high through the 1990s in all the other scenarios even with the increased threat. Nor will survivability change dramatically over time under the alternative program (without the B-1B but with improvements to the B-52s and an increased buy of ALCMs). Again, with the exception of the most stressful scenario, differences in survivability over time are within 11 percentage points and indeed, in most cases, are less than 5 percentage points.

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6. Depressed trajectories are powered missile flight paths that could decrease significantly the time of flight to target. Programming SLBMs to fly these trajectories is difficult, and it is reported that the Soviets have not yet developed this capability.

Survivability Does Not Differ Dramatically Between Options

Survivability does not differ dramatically between the Administration's force and the alternative force. In the alternative force, the alert rates are somewhat lower because there are more older aircraft; also, fewer alert aircraft survive. This occurs, in part, because the B-1B, which is not present in the alternative force, can escape from its base more quickly and is more resistant to nuclear effects. However, differences are relatively small. Except in the most stressful scenario mentioned above, in which the contributions of a harder, faster airplane become more important, differences in survivability between the two forces are less than ten percentage points and, in most cases, are less than five percentage points.

Reaction Time Is Key Variable

Figures E-3 and E-4 show representative cases that illustrate the effect of changing one variable. Two cases illustrate the effects of time-dependent variables on bomber pre-launch survivability (PLS) and two illustrate the effects of structural variables on bomber PLS.

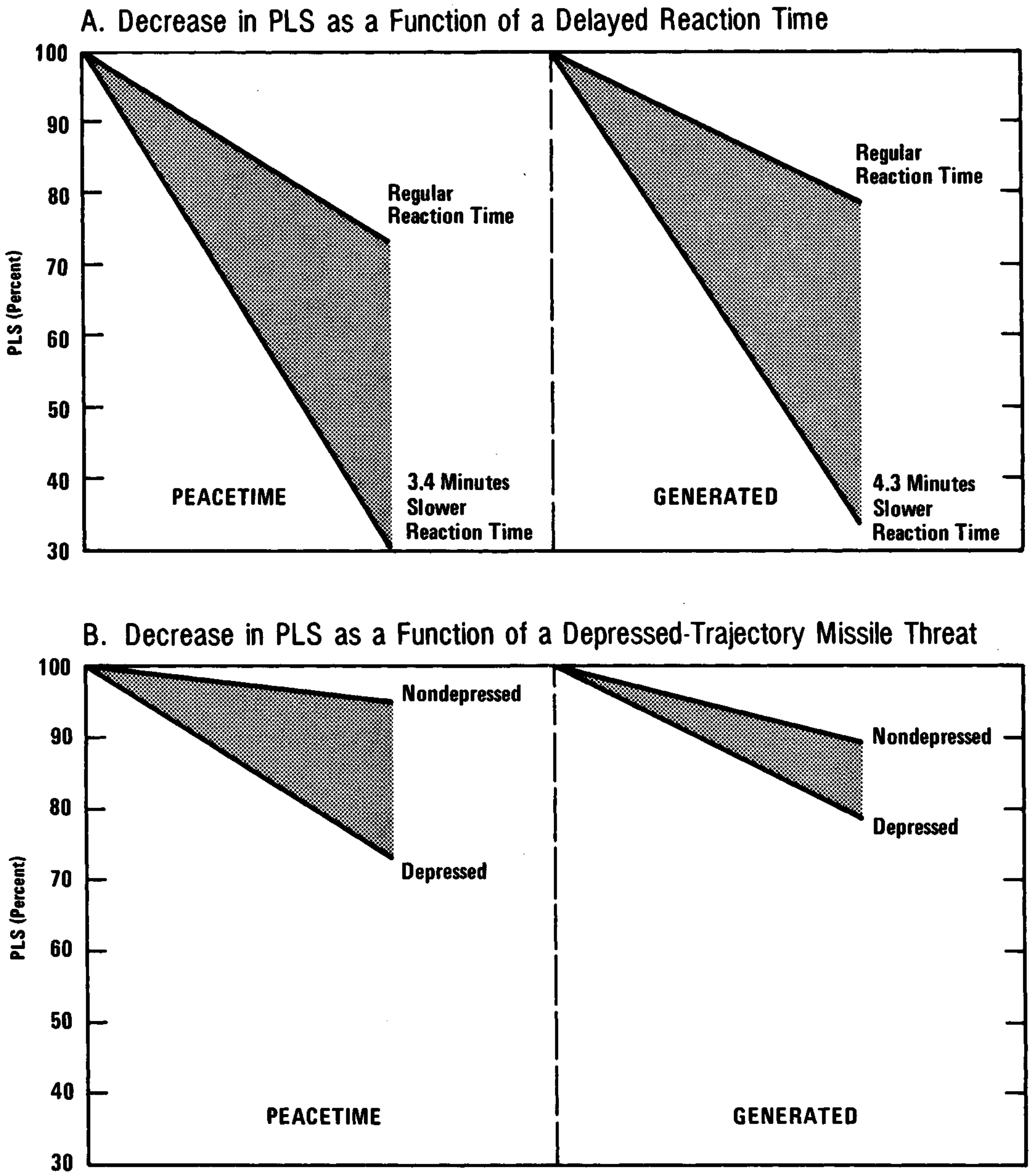
The effects of changes in reaction time are substantial. The upper chart in Figure E-3 illustrates, with the 1990 Administration force, the expected decrease in bomber PLS from a delayed reaction time to warning of an attack. In the peacetime alert case, which represents a 3.4 minute increase in reaction time under a depressed-trajectory SLBM threat, PLS decreases 43 percentage points. In the generated alert case, which represents a 4.3 minute increase in reaction time (equal to a peacetime alert reaction time) under a depressed trajectory SLBM threat, PLS decreases 45 percentage points.

The potential future ability of the Soviets to fire missiles on depressed trajectories is also important. The lower chart in Figure E-3 illustrates, with the 1990 Administration force, the expected decrease in bomber PLS from a depressed-trajectory threat from Soviet SLBMs. In the peacetime alert case, the expected decrease in survivability, from this effect alone, is 22 percentage points. In the generated alert case, the expected decrease in survivability is 10 percentage points. For the generated case, where the bomber reaction time is assumed to be about four minutes faster, the faster flight time of the attacking missiles does not have as great an effect on bomber PLS.

Figure E-4 illustrates the effects of changes in structural variables. The upper chart in Figure E-4 shows the expected decrease in bomber PLS from an older as compared to a newer composition of bomber force. In the

Figure E-3.

Time-Dependent Variables



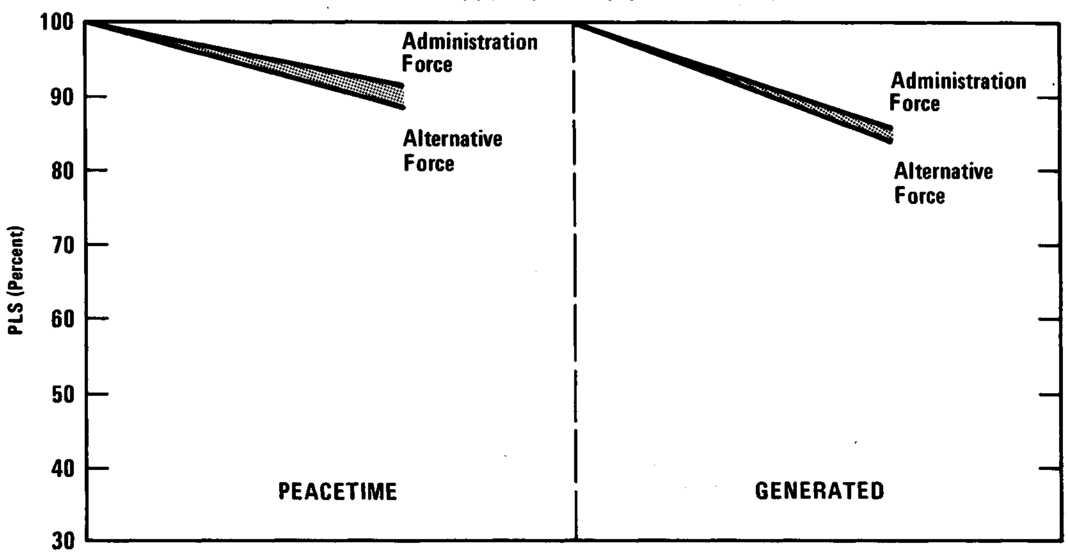
SOURCE: Congressional Budget Office.

NOTE: PLS = Pre-launch survivability.

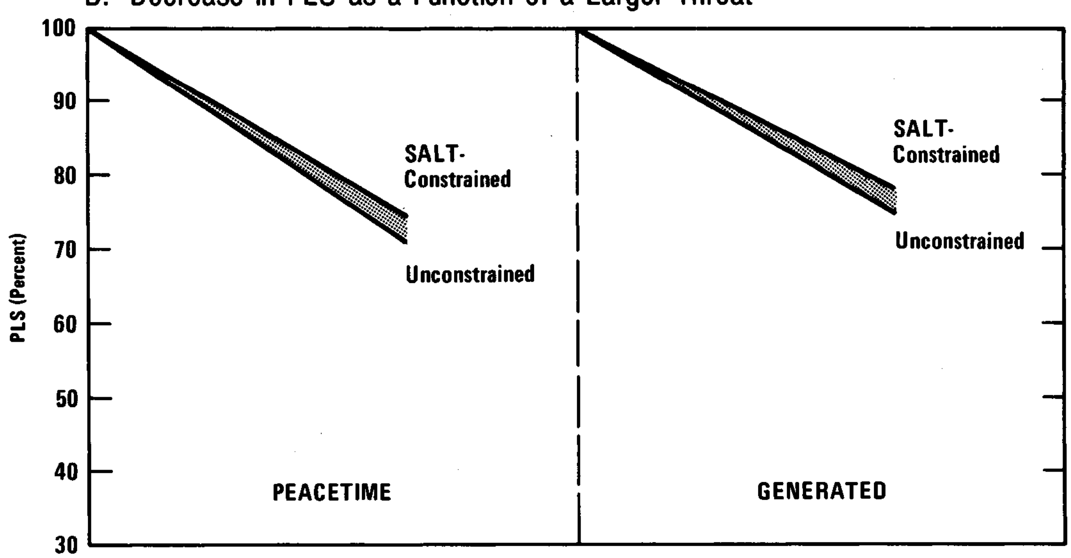
Figure E-4.

Structural Variables

A. Decrease in PLS as a Function of an Older vs. a Newer Bomber Force



B. Decrease in PLS as a Function of a Larger Threat



SOURCE: Congressional Budget Office.

NOTE: PLS = Pre-launch survivability.

1996 alternative force, older B-52Gs take the place of B-52Hs, and B-52Hs take the place of B-1Bs. Both forces have the same number of Advanced Technology, or "stealth" bombers, and the basing locations and threat are identical. Thus, the effect of the older force is to reduce expected bomber PLS by three percentage points in the peacetime alert case and by one percentage point in the generated case. Under a depressed-trajectory missile threat (not shown), these figures become eight and six percentage points respectively.

The lower chart in Figure E-4 illustrates the expected decrease in bomber PLS from an increase in the size of the threat or number of attacking SLBMs. Under an unconstrained threat, bomber PLS is about three percentage points less for the 1996 Administration force in both the peacetime and generated alert cases than under a SALT-constrained threat. This is the result of an increase of about 300 attacking SLBM warheads in the peacetime case and about 550 attacking SLBM warheads in the generated case. These differences in the effects of time-dependent variables as compared to structural variables on bomber survivability appear consistently throughout the analysis. The important caveat is that these results are only applicable to bomber pre-launch survivability. The importance of structural changes, such as the introduction of harder, faster aircraft may be profound for the bomber's retaliatory mission when it must face a stressful flight profile, air defense threats, and so on. However, the results indicate that those factors that lengthen or shorten the interval between first missile launch and first bomber flyout are the most critical to the initial survivability of the bomber force in a submarine-launched attack.

APPENDIX F. EXISTING ARMS-CONTROL AGREEMENTS

The two Strategic Arms Limitations Treaties, SALT I and SALT II, have in the past influenced the shape of U.S. strategic offensive and defensive forces and may continue to do so in the future. Although none of their limitations on strategic offensive arms are legally in force, a brief review of the important features of the treaties will help in understanding their possible effects on Administration plans.

The SALT I Treaty 1/

SALT I--signed, ratified, and entered into force by the United States and the Soviet Union in 1972--is an umbrella term for its two major agreements, the Anti-Ballistic Missile (ABM) Treaty and the Interim Agreement on Strategic Offensive Arms. 2/ The ABM Treaty and its 1974 Protocol, by limiting each party to only one ABM site with no more than 100 interceptor missiles and launchers, effectively precludes either side

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1. Much of the material in this section is drawn from United States Arms Control and Disarmament Agency, Arms Control and Disarmament Agreements. Other treaties and agreements to which the United States is a party can also influence the structure of U.S. strategic forces, albeit in a more indirect way than SALT. For example, the Outer Space Treaty, Seabed Arms Control Treaty, Limited Test Ban Treaty, Threshold Test Ban Treaty, and the "Hot Line" agreements all affect in some way the kinds of forces built and how they are operated. The focus here is on the SALT agreements because of their more direct limitations structures.

2. The complete titles of these agreements are, respectively, the "Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems" and the "Interim Agreement Between the United States of America and the Union of Soviet Socialist Republics on Certain Measures With Respect to the Limitation of Strategic Offensive Arms."

from deploying a wide-area, nationwide ballistic missile defense network. 3/ Further limitations contained in the Treaty and its agreed statements set specific limits on research and development, dual use of surface-to-air missiles in an ABM role, and exploitation of other environments for ABM deployment. One of the more interesting features of the ABM Treaty is its establishment of the Standing Consultative Commission (SCC) for discussion and resolution of questions and problems raised by either party concerning the ABM Treaty or the Interim Agreement. The ABM Treaty is subject to review every five years and contains specific provisions for amendment and withdrawal; it is of unlimited duration.

The Interim Agreement (IA), on the other hand, establishes certain numerical limits on the number of ICBM and SLBM launchers and modern SSBNs. The IA sought, in effect, to freeze for five years the further deployment of ballistic missile launchers, while allowing some latitude for substitution of SLBMs for ICBMs. The freeze having been imposed, it was believed that a follow-on agreement could then be negotiated. Numerically the Agreement limits the United States to no more than 1,054 ICBM launchers and 656 SLBM launchers in 41 SSBNs (or 710 launchers in 44 SSBNs if the Titan II ICBM silos were to be dismantled). 4/ Of perhaps equal interest is the codification of certain arms-control concepts in the IA, including that of using missile launchers as the primary unit of measurement; "heavy" ICBMs; land-mobile launchers; modern SSBNs; and verification provisions, all of which have been applied in subsequent agreements. Other definitions and procedures--especially those for retiring existing systems--have been developed through the SCC.

SALT II

The follow-on, more permanent agreement envisioned in SALT I took shape as SALT II, signed in 1979.5/ Withdrawn from active consideration for

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3. A 1974 Protocol to the Treaty reduced the number of ABM sites allowed each side from two to one, either the national capital or an ICBM site. The United States chose Grand Forks, North Dakota, as its site, while the Soviets chose Moscow.

4. The Soviets are limited to 1,618 ICBM launchers and 740 SLBM launchers. They are permitted to trade up to 210 ICBM launchers of "older types" (that is, pre-1964) for SLBM launchers, which they have done.

5. Officially called the "Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Strategic Offensive Arms."

ratification consent by the Senate since early 1980, SALT II consists of three major sections: a Joint Statement of Principles, a now-expired Protocol, and a main agreement with a December 31, 1985 termination date. 6/ In brief, the Protocol banned mobile ICBM launchers, deployment (but not testing) of cruise missiles capable of ranges in excess of 600 kilometers, and testing or deployment of air-to-surface ballistic missiles (ASBMs). The main Treaty contains the codification of numerical limitations on strategic offensive forces. Simply put, these include:

- Overall limit on Strategic Nuclear Delivery Vehicles (2,250): long-range heavy bombers, ICBM and SLBM launchers.
- Sublimit 1 (1,320): Launchers of MIRVed ballistic missiles, plus long-range heavy bombers capable of cruise missile carriage.
- Sublimit 2 (1,200): Launchers of MIRVed ballistic missiles.
- Sublimit 3 (820): Launchers of MIRVed ICBMs.

In addition, each side was allowed to develop and deploy only one new type of ICBM--limited to carrying 10 RVs--and could load no more than 14 RVs on its SLBMs. Numerical limits were established for the RV loadings of existing ICBMs, and a limit of 20 ALCMs per B-52 and B-1 type bomber was imposed.

SALT II also expanded upon some of the concepts outlined in SALT I, among them a ban on additional fixed ICBM launchers; certain ceilings and limits on heavy ballistic missiles; and non-interference provisions related to verification. Thus, SALT II attempted to create a set of ostensibly equal limits, while at the same time allowing some freedom for each side to structure its forces along traditional lines. Two apparent asymmetries in the agreement do exist, namely a Soviet monopoly on heavy ICBMs (set at 308) and the classification of the Soviet Backfire bomber as a non-strategic system. Both points are contentious. Some believe that these differences provide both de facto and de jure advantages to the Soviets, while others view them either as providing no real advantage or as necessary for the culmination of the Treaty.

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6. As with SALT I, SALT II, in its Joint Statement of Principles, contains language that looks forward to future agreements; thus, a finite expiration date was not considered unreasonable.

How SALT Could Affect the Administration Program

Leaving aside for the moment a discussion of the Administration policy on compliance with the SALT accords, it is useful to see how these agreements might affect the Administration modernization initiatives. Because a primary goal of this plan is, in fact, modernization and revitalization of the capital stock in U.S. strategic forces, the discussion here assumes that new forces are preferred to existing forces when a tradeoff must be made.

Beginning with the numerical limits of the SALT I Interim Agreement, the Administration plan could potentially exceed the SLBM launcher limit by the end of 1984 unless, among other actions, the United States either retires the seven remaining ex-Polaris SSBNs--currently operating as SSNs--or removes their launchers in a timely manner in compensation for new Trident submarines. 7/ Given Polaris deactivations, the limit might not be exceeded until 1987 if the silos housing the Titan II ICBMs, scheduled for retirement under the Administration plan, are dismantled in accordance with agreed procedures. 8/ The Administration's plan currently does not include this provision. In the post-1987 period, a revised plan for retirement of some Poseidon submarines would be needed. In contrast to the retirement plan assumed in Chapter II for constructing the illustrative Administration program, approximately 30 percent of these submarines would have to be retired before 1993.

The Administration ICBM program poses no obvious problems with SALT I ICBM launcher limits. Plans for the deployment of the MX in Minuteman silos call for no changes in volume or other dimensions in violation of the Interim Agreement. As for the follow-on deployment of a SICBM in a mobile mode, the IA does not limit mobile missiles. Fixed-point basing of the SICBM in new silos would be inconsistent with the IA.

As for the SALT II accords, the December 1981 expiration of the Protocol allows both the deployment of the ALCM and any mobile missile

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7. In accordance with agreed procedures, the retiring submarine must be located in an industrial facility, capable of performing the required work, by the time the new submarine commences sea trials. Dismantling of the compensating submarine must then be completed within six months.

8. As noted earlier, this would allow the limit on SLBM launchers to increase from 656 to 710, and on modern SSBNs from 41 to 44.

deployments to proceed. Testing and deployment of both the MX and the SICBM would violate the "one new type" rule for light ICBMs permitted for each side.

Meeting the numerical limits of SALT II would pose some difficult choices on the Administration program in the mid-1980s, not only because of the buildup in the sea-based force noted earlier, but also because of the air-launched cruise missile program and the potential for deploying a relatively large number of small ICBMs. The difficult choice would occur in attempting to satisfy simultaneously the 1,320 and 1,200 MIRV sublimits. Because most existing systems would be retained and new weapons added in numbers from the mid-1980s through the mid-1990s, these limits would be exceeded unless action was taken to cut back. This would have to involve reducing the numbers of multiple-warhead ballistic missiles or cruise missile-capable bombers. As an example, retirement of about 350 Minuteman III missiles in the late 1980s would maintain compliance with the limits. If it is assumed that the Administration takes the actions noted above for SALT I compliance, it would likely be able to meet the limit on strategic nuclear delivery vehicles throughout the remainder of the century.

In summary, the SALT agreements would appear to place significant constraints on the retention of some existing strategic systems if the Administration wishes to modernize according to its plan. In addition to the already planned retirement of B-52Ds, Titan IIs, and perhaps ex-Polaris SSBNs, the Administration might also have to retire some ballistic missile launchers in the late 1980s and early 1990s to remain within the numerical limits of both agreements. Aside from these constraints--with the possible exception of the "one new type" rule of SALT II--the provisions of neither treaty would appear to hamper the Administration modernization program to any great extent.

Cost Differences Associated with SALT Compliance

Pursuing the major modernization initiatives of the Administration plan while simultaneously observing the SALT limits would not cause significant changes in the cost of the program either in the near term or later. By assumption, the major development and investment costs would remain virtually unchanged; operating costs, on the other hand, would be expected to decline somewhat because of the early retirement of some systems. These savings, in turn, would probably be offset by the additional cost incurred by retiring systems in accordance with SALT-prescribed criteria. Table F-1 shows the cost differences between the Administration program as outlined in Chapter I and the SALT-constrained illustrative program described above.

TABLE F-1. OPERATING COST SAVINGS OF THE ADMINISTRATION'S PROGRAM CONSTRAINED BY SALT (By fiscal year, in millions of fiscal year 1984 dollars)

Cost Category	1984	1985	1986	1987	1988	Total 1984-2000
Budget Authority	--	--	32	87	118	5,651
Outlays	--	--	18	57	91	a/

a/ Outlay savings provided for 1984-1988 only.

Effectiveness of the SALT-Constrained Administration Plan

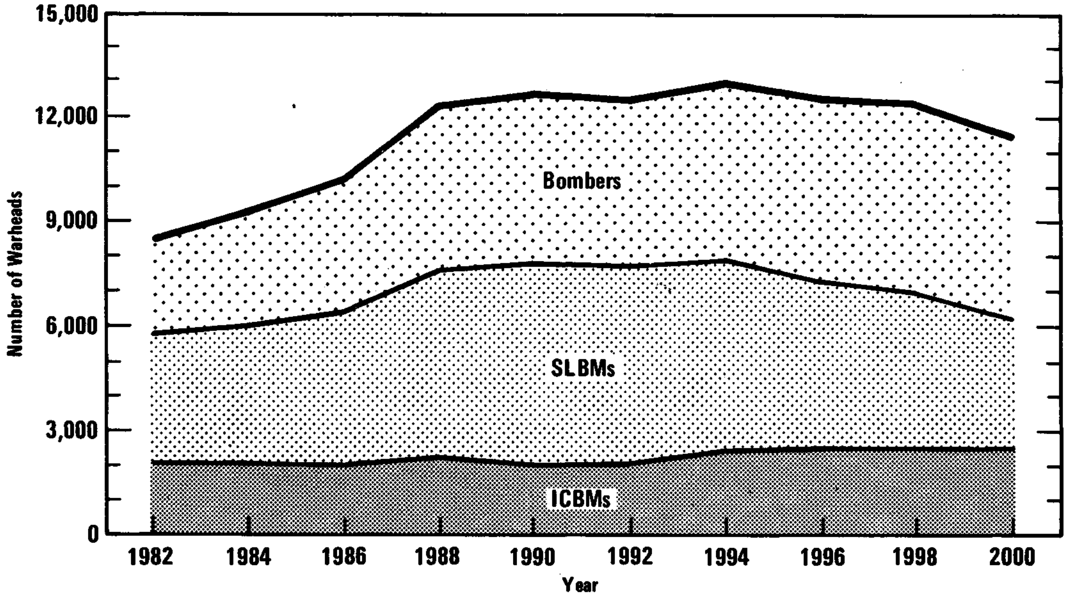
Using the same measures of effectiveness and methodology as introduced in Chapter II, CBO examined the effectiveness of the force created through the illustrative series of program modifications outlined above. Figure F-1, for example, shows how the number of on-line warheads would change over time under this modified plan. The effects of retiring some ICBM and SLBM forces in the late 1980s and early 1990s are apparent. While a substantial buildup in on-line warheads would still occur through the early 1990s, the increase--and subsequent decrease out to the end of the century--would not be as dramatic as in the unconstrained case shown in Figure 4; the peak warhead count would decline from over 13,000 to around 11,600. This peak would be some 48 percent higher than 1983 warhead levels, and the warhead count at the end of the century would be about 32 percent higher than in 1983.

After absorbing a Soviet first strike launched either with or without warning, the SALT-constrained force would have about 6 percent fewer warheads than the unconstrained Administration force in 1990. 9/ Since planned retirements and continued modernization would be similar for both

9. The illustrative SALT-constrained forces used in making these estimates are shown in Appendix C.

Figure F-1.

Evolution of Strategic Force Buildup Under SALT Constraints, by Triad Element, 1982-2000



SOURCE: Congressional Budget Office.

forces in the late 1990s, the surviving warhead levels by 1996 would be much the same. Because all Administration modernization plans could fit under the SALT numerical limits, surviving hard-target weapons would be virtually equal for the two forces in 1990 and 1996.

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